SURFACE ENGINEERING IMPACTS ON HYDROGEN CHARGING AND HARDNESS OF HIGH STRENGTH STEELS

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Processing of many engineering components containing martensitic steels often involves surface engineering steps such as shot peening, laser shock peening, or induction heat treating. These processes are geared at creating compressive stresses in the near surface region of parts, most often with the intent of increasing fatigue life or decreasing fracture or wear. Shot peening in particular can lead to mechanically roughened surfaces due to localized plastic deformation. Hydrogen interactions with surface textures (and possibly stresses) impacts pickup, and hydrogen interactions with dislocations impacts mechanical reliability. Therefore, the complexity of the stress states, the phases present, and the dislocation density all may impact the overall reliability of steels with martensitic phases in the presence of hydrogen.

Three steels, a conventional medium carbon steel which was quenched and tempered (1070) and high strength (DP1180 and a 100XF) were used as the testbed for these experiments. Shot peening was used to create surface compressive residual stresses by peening to an Almen intensity of approximately 15A. Hydrogen charging was carried out using laboratory scale electrochemical charging; recognizing that prior studies have demonstrated differences between electrochemical and gas phase charging in shot peened samples of other steels [1] we have tested both polished and as-peened conditions to attempt to remove uncertainty due to surface roughness variations in the samples. Mechanical properties (plastic, elastic, and fracture) were assessed using a combination of nanoindentation, ultrasonic testing, and 3-point bend testing respectively. In addition, we compared the residual stress gradient changes in shot peened samples before and after charging based on changes in residual curvature in an Almen gage measurement, where a strain gradient due to peening leads to plate bowing in a fixed geometry. Finally, x-ray diffraction using the cos□method was used to determine the residual strain in the ferritic lattice of tempered and dual phase steel as a function of charging time and after thermal desorption. The cos□method takes approximately 1 minute per measurement, and with a spot size of 2 mm provides the ability to sample gradients and temporally assess changes in strain as samples are charged and hydrogen subsequently desorbed.

By comparing changes in hardness and lattice parameter upon charging peened samples with those using only similarly scaled applied mechanical stress provided the opportunity to assess changes based on dislocation density. We will explain the observed differences in hydrogen uptake in relationship to the extent of hardening in steels with martensitic phases based on dislocation content inferred from changes in hardness in the pre-charged state. Additionally, increases in hardness post-charging will be put in relationship to the slip traces and pile up around indentations impressions that suggest planar slip that is enhanced by hydrogen pick up may be offset in part due to compressive stress.

Reference:

1. Makoto Kawamori, Wataru Urushihara, Satoshi Yabu, ISIJ International, 2021, 61, 1159-1169.